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Growth and future trends of wind energy in India

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Abstract

In India, the wind power generation has gained a high level of attention and acceptability compared to other renewable energy technologies. New technological developments in wind power design have contributed for the significant advances in wind energy penetration and to get optimum power from available wind. The yearly percentage increase in wind energy installation is highest for India and now ranks fourth in the world with an installed capacity of 6018 MW. This paper reviews the development of wind energy in India and five potential Indian states. The future growth pattern and time period to achieve the technical wind potential are predicted and analysed.

Keywords: Growth curve; Logistic model; Renewable energy; Wind energy technology

Contents

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1. Introduction

Growing concern for the rise in fossil fuel prices and environmental degradation has led to the world's interest in renewable energy sources. Wind is commercially and operationally the most viable renewable energy resource and accordingly emerging as one of the largest source in renewable energy sector. Wind energy is a clean renewable energy source that hold out the promise of meeting energy demand in the direct, grid connected modes as well as stand alone and remote applications.

India has a good potential of wind throughout the country. Winds in India are influenced by the strong south-west summer monsoon, which starts in May–June, when cool, humid air moves towards the land and the weaker north-east winter monsoon, which starts in October, when cool dry air moves towards the ocean. During the period of March–August, the winds are uniformly strong over the Indian Peninsula, except the eastern peninsular coast. Winds during the period from November to March are relatively weak in India, though higher winds are available during a part of the period on the coastline of the state of Tamilnadu. As a result of scientific assessment of wind resources [1–4] throughout the country, wind power has emerged as a viable and cost effective option for power generation.

In India, power generation from wind has emerged as one of the most successful programme in the renewable energy sector and is making meaningful contributions to the overall power requirements in some of the states. The Ministry of New and Renewable Energy (MNRE) (earlier called as the Ministry of Non-Conventional Energy Sources (MNES)) is the nodal ministry of Government of India for all matters relating to new and renewable energy. As per the projections made by MNRE, India, 10% of the total capacity of power generation will come from renewable energy sources by the year 2012. It is envisaged that 50% of this capacity may come from wind power. India has now gained sufficient technical and operational experience and is now on the threshold of "taking off" in wind power sector.

2. Worldwide scenario

There is a considerable progress in the wind power industry over the last decade in the world. The wind energy technology has established a sound technical feasibility and is therefore one of the promising renewable energy source. Wind power technology is experiencing a major growth especially in United States, Europe and with significant growth in developing countries such as China and India. The top five countries of the wind power market are Germany, Spain, USA, India and Denmark and their installed capacities of wind power is shown in Table 1. India leads in percentage increase of installation capacity with an average annual increase of 33.57% for the past 4 years. Fig. 1 shows the development of wind power in the top five countries from the year 2002 to June 2006 [5]. It

Table 1
Installed capacity of top five countries of world wind power market as on June 2006 (Source: [5])

Country	Germany	Spain	USA	India	Denmark
Installed capacity (MW)	19,540	11,340	10,640	5341	3137

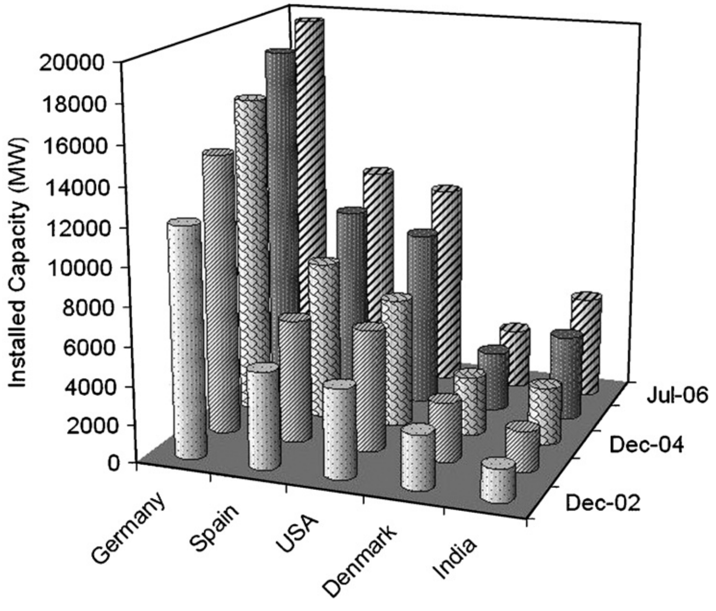


Fig. 1. Growth of wind power in top five countries.

also depicts that India has overtaken Denmark in the year 2005 and ranks fourth in the world.

Worldwide installed capacity of wind power was just 3530 MW in 1994 and it has reached 66,869 MW by the end of June 2006 [5]. Fig. 2 depicts the global growth of wind power, showing an exponential growth in installed capacity. More than 50 countries around the world contribute in the global thrust for the development and harnessing of wind power potential. The future prospects of global wind industry are very promising and it is envisaged that global wind power may cross 160 GW by 2012. The report of Global Wind Energy Outlook has examined the future potential of wind power and it says that the wind power sector could supply 16.5% of world's electricity by 2020.

3. Wind energy potential in India

The wind resource assessment programme is being implemented by the Centre for Wind Energy Technology (CWET), an autonomous R&D institution by the MNRE, Government of India in coordination with the state nodal agencies. About 221 wind monitoring stations having mean annual wind power density greater than 200 W/m^2 at 50 m height have been identified for wind power development. According to initial estimates, the wind power potential in India was assessed as around 20,000 MW. It has been re-assessed as 45,195 MW. However, the present exploitable technical potential is limited to 12,875 MW, on account of the limitation of grid capacity in the State grids. The technical potential will go up with the augmentation of grid capacity in the potential states. The state-wise gross and present exploitable technical potential is given in Table 2 as per the report of MNRE, India [6,7]. Fig. 3 shows the wind energy density map of India. High

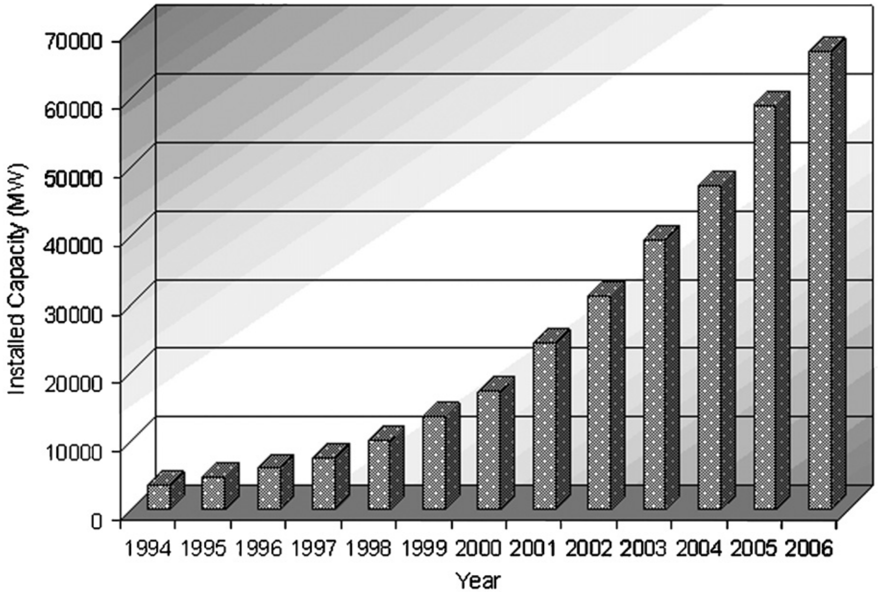


Fig. 2. Global wind power growth.

Table 2
Wind power potential of india (Source: MNRE)

Sl. No	State	Gross potential (MW)	Technical potential (MW)
1	Andhra Pradesh	8275	1750
2	Gujarat	9675	1780
3	Karnataka	6620	1120
4	Kerala	875	605
5	Madhya Pardesh	5500	825
6	Maharastra	3650	3020
7	Orissa	1700	680
8	Rajasthan	5400	895
9	Tamilnadu	3050	1750
10	West Bengal	450	450
	Total	45,195	12,875

wind concentration is mainly in the states of Tamilnadu, Maharastra, Karnataka, Gujarat and Andhra Pradesh.

4. Wind power growth in India

Indian wind energy programme was initiated in 1984. This national programme includes wind resource assessment activities, implementation of demonstration projects, involvement of utilities and industry, development of infrastructure capability and capacity for manufacture, installation, operation and maintenance of wind electric generators and policy support. To open up the potential areas for commercial projects, MNRE

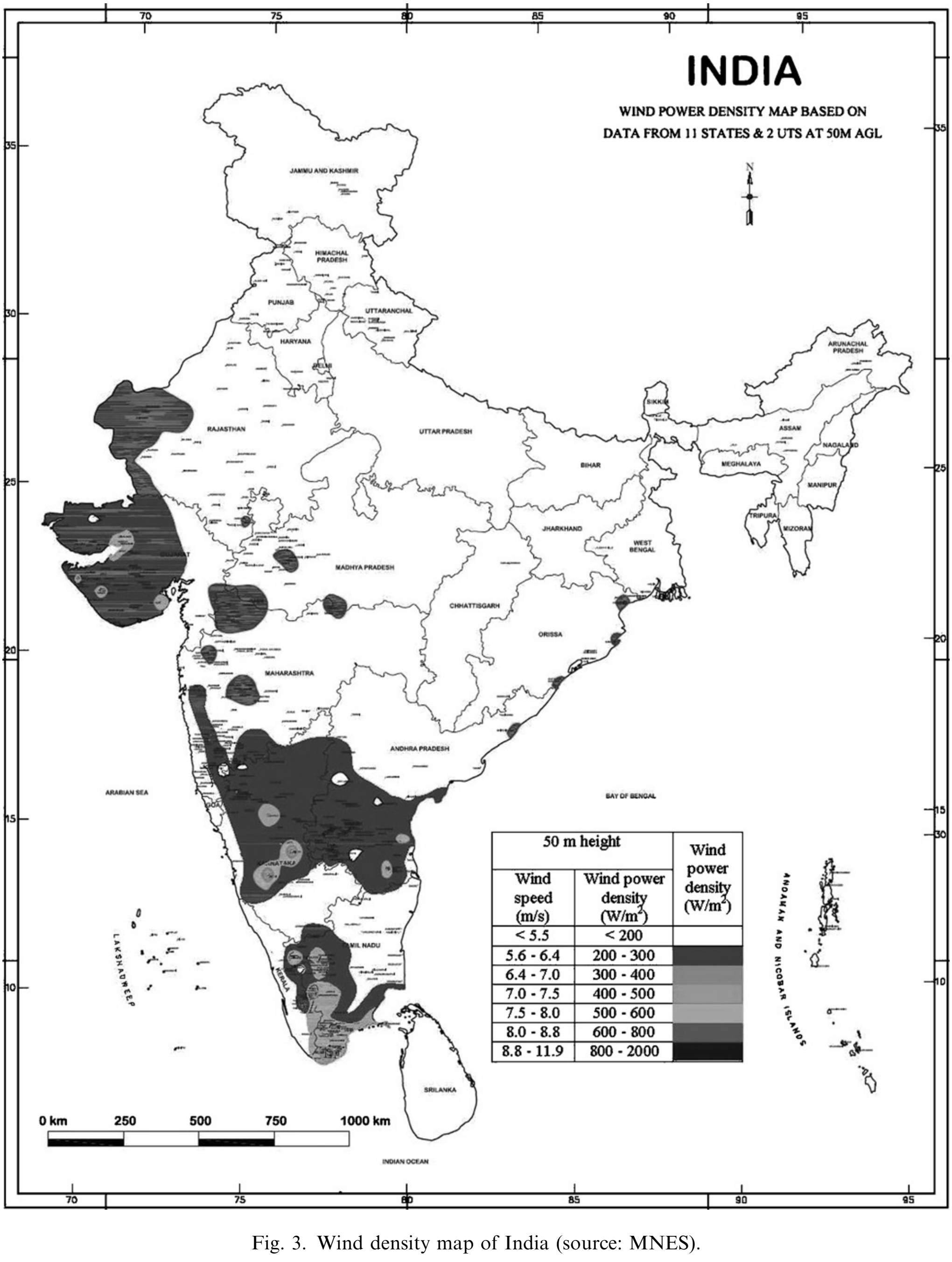


Fig. 3. Wind density map of India (source: MNES).

undertakes demonstration projects at new potential areas or locations. The demonstration projects began in 1985, and are being implemented through the State Governments, State Nodal Agencies and State Electricity Boards. Demonstration projects with an aggregate

capacity of 69.6 MW have been established at 33 locations in nine states. They, together with extremely favourable financial incentives, have created the conditions for the wind energy market to expand from just 32 MW of installed capacity in early-1990. The first commercial project was commissioned on 28 March 1990 at Kattadimalai, Muppandal, Tamilnadu [5]. The Indian Renewable Energy Development Agency (IREDA) which is a Public Limited Government Company, under the administrative control of MNRE to promote, develop and extend financial assistance for renewable energy and energy efficiency/conservation projects, has played a significant role in the promotion of wind energy, attracting bilateral and multilateral financial assistance from world institutions and the private sector.

At first, wind farms in India were installed in the coastal areas of Tamilnadu, Gujarat, Maharastra and Orissa. Now wind farms have been installed in more than nine states of India. In the year 1986, five wind farms of 55 kW wind electric generators were installed with a total capacity of 3.3 MW. In 1988, 110 kW electric generators were introduced [8,9]. Upto March 1992, the wind power installed capacity was 41.18 MW and 20% of this capacity was set up mainly through the demonstration projects of the government. Subsequently, there was a growth in the technology and 400–600 kW wind electric generators were introduced in 1994. After 1996, there was a rapid growth in the installation of wind turbines which increased the total installation capacity. Further improvement in technology led to the installation of 2 MW wind turbine in 2004 and that was the biggest and tallest ever wind turbine generator in Asia. This 2 MW wind turbine was installed at Chettikulam near Koodamkulam in Tamilnadu. The growth of wind power in India from the year 1986 to June 2006 is shown in Fig. 4. Table 3 gives the state wise installed capacity of wind power as on March 2006 and September 2006 [5] showing a surge in this year. It

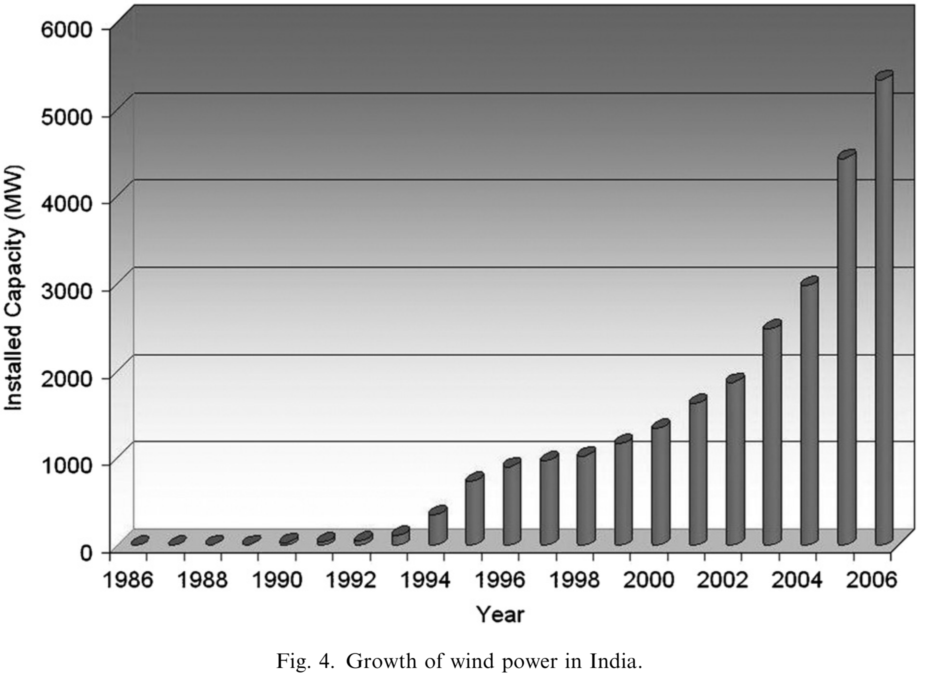


Fig. 4. Growth of wind power in India.

Table 3
State wise installed wind power capacity in India (source: [5])

Sl. No	State	As on 31 March 2006	As on 30 September 2006
1	Andhra Pradesh	121.0	121.0
2	Gujarat	338.1	375.6
3	Karnataka	584.6	687.5
4	Kerala	2.0	2.0
5	Madhya Pradesh	40.3	53.0
6	Maharastra	1001.3	1241.7
7	Rajasthan	358.1	385.9
8	Tamilnadu	2892.5	3148.1
9	West Bengal	1.1	1.6
10	Others	1.6	1.6
	Total	5340.6	6018.0

can be seen that the states of Tamilnadu and Maharastra are leading, where the state of Tamilnadu has contributed 3148.1 MW which is more than half of the total installed capacity of India.

India now ranks fourth in the world wind power market after Germany, USA and Spain as detailed in Table 1. The installed capacity of wind power in India has reached 6018 MW by September 2006 with an aggregate generation of about 24,600 million units of electricity. Out of this total wind power installed capacity, around 95.5% constitute private projects and the rest are demonstration projects. The largest installation of wind turbines in the country so far has been in Muppandal area near Kanyakumari in Tamilnadu. The aggregate capacity of Muppandal area is more than 1457 MW which represents the largest concentration of wind farms at a single location in India. The MNRE sources plans to add 10 GW of renewable energy capacity by 2012 and it is hoped that more than 50% of this capacity comes from wind power.

5. Status of wind power industry in India

The development of wind power industry is driven by the initiative of the MNRE. Compared with other renewable energy technologies wind energy technology is receiving increasing emphasis since 1992, with the backup of private participation. There is a perceptible shift in government strategy in favour of renewable energy technology. Indian government subsidy programmes and private sector participation has achieved tremendous growth in wind power industry with the use of attractive fiscal incentives (accelerated depreciation, low-cost credit, and reduction in customs and excise duties) and accommodating power wheeling and banking contracts from state electricity boards. Large scale development of commercial projects is currently taking place in Gujarat, Karnataka, Maharastra and Tamilnadu states. Public sector undertakings, public utilities and corporate houses are being encouraged to invest in commercial wind power projects to meet partly their power requirements and also to avail the financial and fiscal incentives [10–12].

India has become fourth largest wind power market in the world, its broad-based industrial resources represents an attractive manufacturing platform for wind turbine

companies and most leading manufacturers in the world have invested for manufacturing facilities in India. Indian costs of wind energy equipment is largely determined by international prices due to the involvement of major international manufacturers in the Indian market, usually in partnership with Indian companies. The growing success of wind power has convinced developers and manufacturers internationally and in India to develop and own wind power projects. State-of-the-art technology is now available in India for manufacturing wind electric generators of capacity from 225 to 2000 kW. About 12 manufacturers are engaged in the production of wind turbine equipment [7,13]. The C-WET has published seven volumes of handbooks on Wind Energy Resource Survey in India covering 208 sites.

6. Future trends in India

Modelling serves as a base for predicting the wind energy scenarios of future growth pattern. Technological forecasting is a method used to estimate the growth and direction of any technology. Different growth patterns are being used for technological forecasting. In this paper, the fundamental form of growth curve, called the Pearl curve or logistic curve is used. The logistic curve has been used for many years in estimating biological growth phenomena and also as a convenient tool for forecasting of industrial growth. The logistic curve is used to model a variety of physical situations in which a parameter's growth is self-limited, that is, the growth rate of the parameter depends on the size of the parameter in such a way that if the parameter grows beyond the inflection point, the growth rate decreases.

The general form of Pearl or logistic function is given by

$$Y = L/(1 + a\mathrm{e}^{-bt}),$$

where L, a and b are positive constants and Y is the state of information at time t [14,15].

The growth study is carried out using the Pearl or the logistic curve to predict the overall future trends of Indian wind power industry and also in five states, namely, Tamilnadu, Maharastra, Karnataka, Gujarat and Andhra Pradesh. These five states have high technical wind energy potential of more than 1000 MW and show a rapid growth in recent years. The installed wind power capacity data for a period of 15 years from the year 1991 to 2006 is taken for forecasting the future trends of India and the five potential Indian states. Table 4 gives the values of L, a and b of the logistic curve function. The values of a

Table 4
Upper limit and regression coefficients of the logistic function

State	Upper limit, L	Regression coefficients	
		a	b
Tamilnadu	7000	151.81	0.3069
Maharastra	12,080	42580.00	0.5741
Karnataka	4480	23607.00	0.5473
Gujarat	7120	312.32	0.1952
Andhra Pradesh	7000	6156.00	0.3873
India	51,500	782.22	0.3072

and b are estimated by using the past data of wind power capacity. The upper limit L is calculated from the technical wind power potential. The technical wind power potential in India and the five Indian states are given in Table 2. Due to the intermittent nature of wind energy, more capacity of wind electric generators has to be installed to attain the assessed technical wind power potential. Accordingly, the capacity to be installed is given by, the technical wind power potential divided by the average annual capacity factor. The average annual capacity factor is assumed as 25% based on the available previous years data. The designed capacity to be installed to achieve the technical wind power potential of India and five potential Indian states, Tamilnadu, Maharastra, Karnataka, Gujarat and Andhra Pradesh are 51,500, 7000, 12,080, 4480, 7120, 7000 MW, respectively. These capacities are taken as the upper growth limit for forecasting the growth pattern. Technological influence and the capital cost of the plant are assumed to remain constant in the future.

The projected installation of wind electric generator capacity with respect to time scale to achieve India's wind energy potential is shown in Fig. 5. The S-shape characteristic of the graph indicates that during early years, from region p to q, the growth is very slow. This indicates the resistance to implement new technology. After this sluggish growth region, the growth increases exponentially from q to r and then again the growth slows down while approaching the maximum upper limit. The projected capacity addition every year is depicted in Fig. 6. It infers that the growth or the capacity addition is increasing up to the inflection point O, which corresponds to the year 2013. Then the growth rate slows down gradually as the installation capacity approaches the upper bound.

Table 5 gives the projected potential that can be attained over the given time period in India corresponding to the projected installation capacity. In India, the growth of wind power technology is tremendous for the last few years and if the same trend continues further, according to the study it can be expected that by the year 2030, the installed capacity of wind power may reach 51,249 MW. This corresponds to 12,812 MW of wind

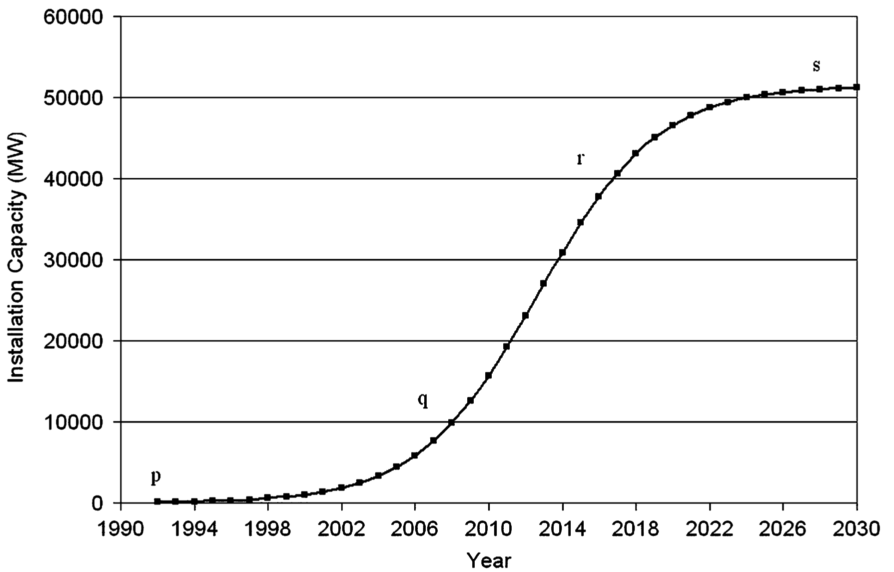


Fig. 5. Projected wind installation capacity of India over the given time period.

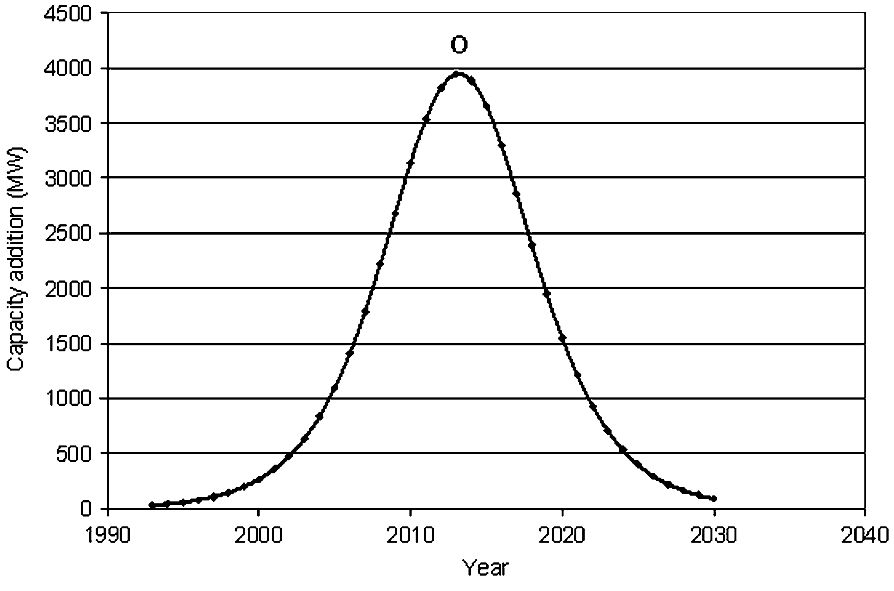


Fig. 6. Projected capacity addition of India for the given time period.

Table 5
Projected potential that can be attained over the given time period in India

Year	Projected value of installation capacity (MW)	Projected value of potential that can be attained (MW)
2007	7641	1910
2010	15,682	3921
2015	34,524	8631
2020	46,570	11,643
2025	50,353	12,588
2030	51,249	12,812

energy potential, which can be fed to the grid. This result indicates that the dissemination of wind energy technology for power generation in India may reach 99% of the assessed total technical wind power potential by the year 2030.

Figs. 7 and 8 give the projected installation capacity and the capacity addition in MW per year of the five states taken for study. It can be seen that the states of Maharastra and Karnataka have a growth pattern in same pace and appears to reach the inflection point in the year 2010. After this year the growth rate declines and reaches the saturation level. The study reveals the diffusion of wind energy technology may reach 99% of the technical potential of 3020 and 1120 MW by the year 2020. In Tamilnadu, wind power technology has already gained importance showing a good progress in the development. The inflection point for Tamil Nadu is in the year 2008 and may reach 99% of its total technical potential by the year 2022. However, in case of Gujarat, the growth rate is very slow and reaches the inflection point by the year 2021. Upto June 1998, there was good progress in wind energy

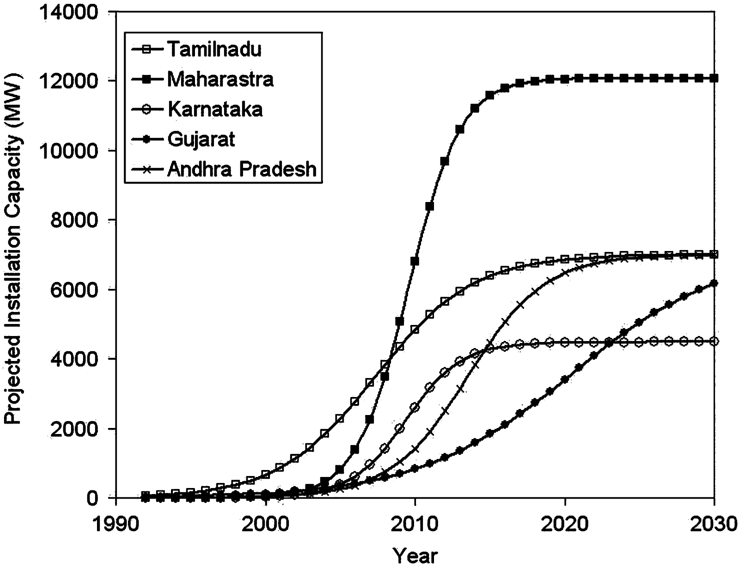


Fig. 7. Projected wind installation capacity of the five potential Indian states over the given time period.

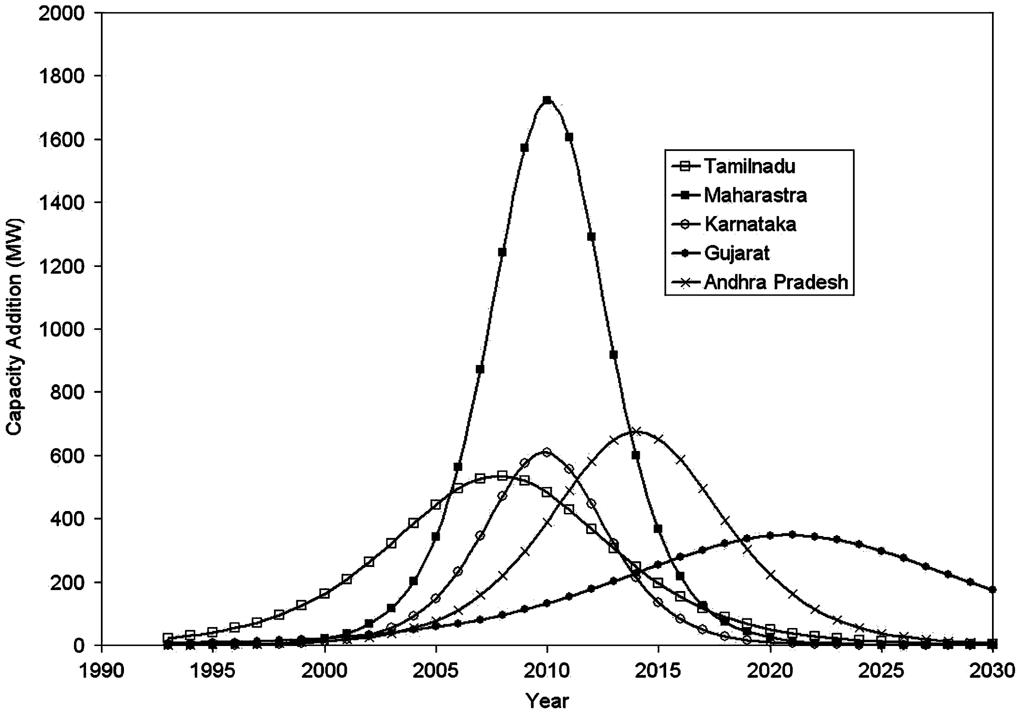


Fig. 8. Projected capacity addition of the five potential Indian states for the given time period.

Table 6
Projected potential that can be attained over the given time period in high-potential states

	Year	State				
		Tamilnadu	Maharastra	Karnataka	Gujarat	Andhra Pradesh
Projected value of installation capacity (MW)	2007	3304.3	2252	949.5	482.6	516.9
	2010	4842.9	6788	2604.6	822.4	1421.3
	2015	6386.8	11,569	4280.3	1832.3	4469.6
	2020	6858.1	12,050	4466.5	3410.6	6471.5
	2025	6968.9	12,078	4479.1	5050.1	6918.5
	2030	6993.3	12,080	4479.9	6167.4	6988.1
Projected value of potential that can be attained (MW)	2007	826	563	237	121	129
	2010	1211	1697	651	206	355
	2015	1597	2892	1070	458	1117
	2020	1715	3012	1117	853	1618
	2025	1742	3019	1119	1263	1730
	2030	1748	3020	1120	1542	1747

technology in Gujarat, but unfortunately due to cyclone, it suffered a major set back [16]. After 2003, it is slowly picking up and according to the study it may achieve 86% of its technical potential only by the year 2030. Andhra Pradesh shows a gradual and steady increase in harnessing its technical wind potential. The state may attain the inflection point in the year 2014 and tends to accomplish 99% of the state's total technical wind potential by the year 2025. The potential that can be attained over the given time period in high-potential Indian states corresponding to the forecasted capacity is given in Table 6.

7. Conclusions

Wind energy technology is currently making a significant contribution to the electric power generation systems in India. Now India is one of the leading countries in the world for the development and utilisation of wind energy. The gross and technical wind energy potential in India is assessed as 45,195 and 12,875 MW by CWET. The wind energy growth pattern of India is reviewed since its inception in 1984. The status of five potential Indian states is also analysed separately.

Based on the growth trends, the future of wind energy in India is predicted using logistic function and found that 99% of India's technical wind energy potential may be achieved by the year 2030. Of the five potential Indian states, Maharastra and Karnataka show relatively a steep rise compared with other states. The political atmosphere and policies in India is conducive to achieve the technical wind power potential of India.

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